sPHENIX Detector Overview

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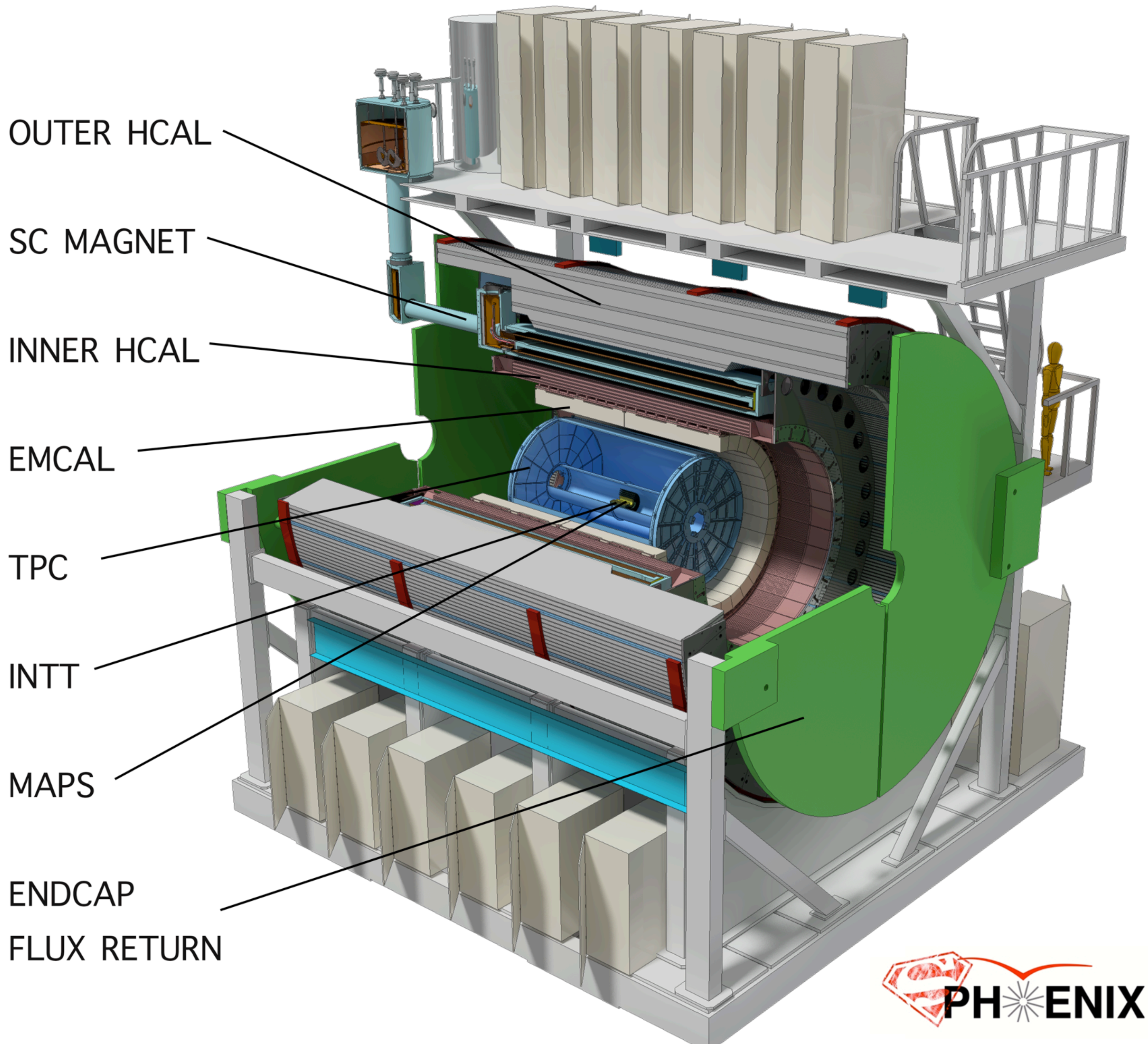
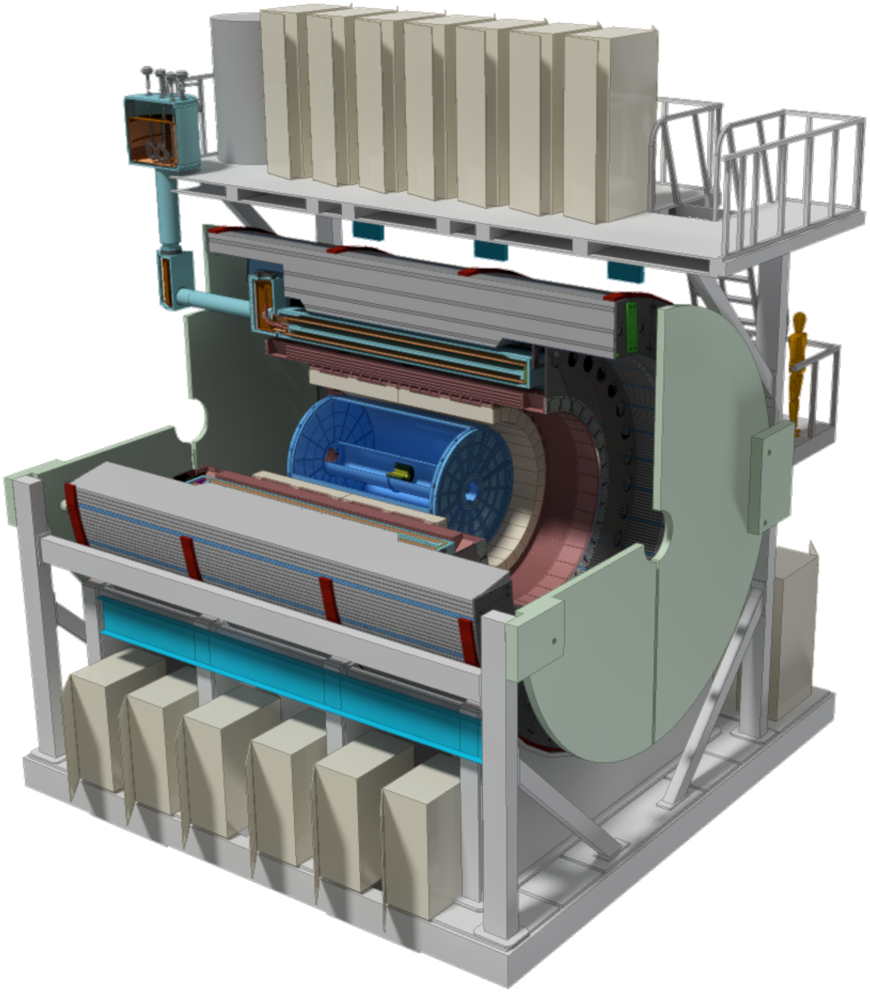
What is sPHENIX?

- sPHENIX is a proposal for a major upgrade to the PHENIX detector capable of making high statistics measurements of:
  - Jets with tracking and calorimetric reconstruction
  - Jets correlations
  - Upsilon states
- A proposal in July 2012 led to the DOE reviews in July 2014 and May 2015 affirmed the science case which was subsequently included in the September 2015 NSAC Long Range Plan and led to a CD-0 approval September 2016
- A new sPHENIX collaboration was formed in December 2015 which continues to grow to realize this detector and harvest its physics


OUTER HCAL
SC MAGNET
INNER HCAL
EMCAL
TPC
INTT
MAPS
ENDCAP
FLUX RETURN
sPHENIX

Scope of sPHENIX MIE



WBS	sPHENIX MIE Project Elements
1.1	Project Management
1.2	Time Projection Chamber
1.3	Electromagnetic Calorimeter
1.4	Hadron Calorimeter
1.5	Calorimeter Electronics
1.6	DAQ-Trigger
1.7	Minimum Bias Trigger Detector

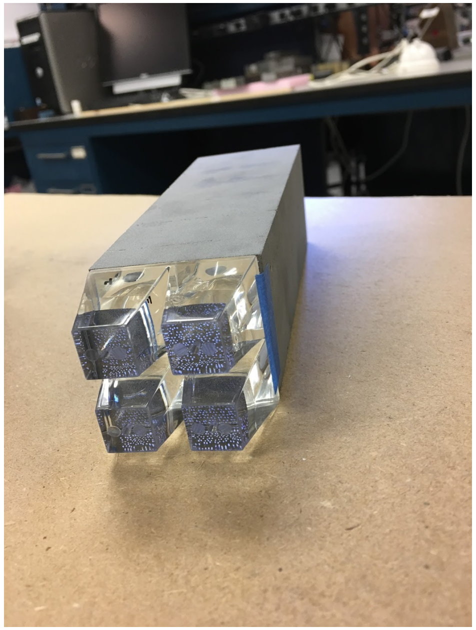
WBS	Infrastructure & Facility Upgrade
1.8	SC-Magnet
1.9	Infrastructure
1.10	Installation-Integration

WBS	Parallel Activities
1.11	Intermediate Silicon Strip Tracker
1.12	Monolithic Active Pixel Sensors

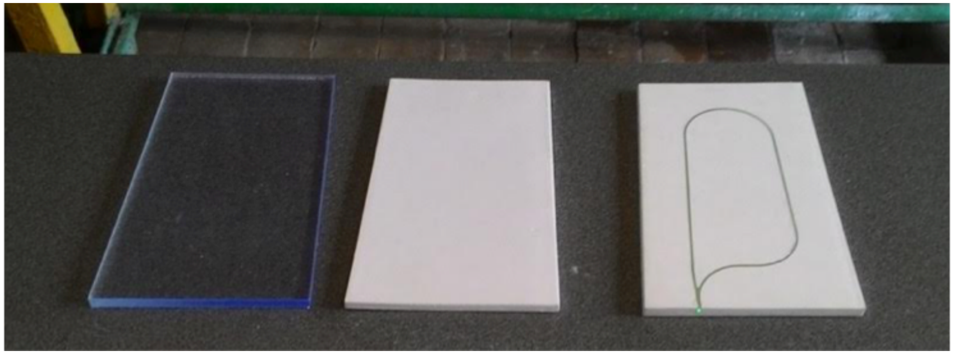
The sPHENIX Detector—Calorimetry

- Novel sampling hadronic and electromagnetic calorimetry
  - "Tilted plate" HCAL populated with extruded scintillating tiles with light collected by embedded fiber
  - Tungsten-scintillating fiber SPACAL with ~7 mm radiation length allows for compact design which can fit inside the solenoid
  - In both calorimeters, light collected to SiPM's which are
    - Compact
    - Don't require high voltage
    - Work in magnetic field
    - Large signal that allows us easily to cable out analog signal
  - Common electronics including low cost 60 MHz waveform digitizers

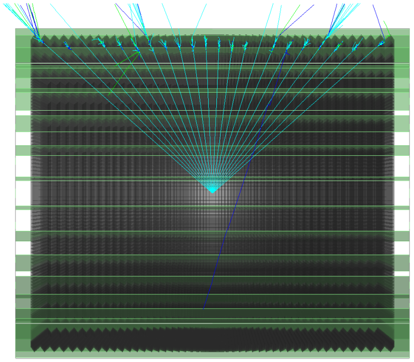
Calorimeters

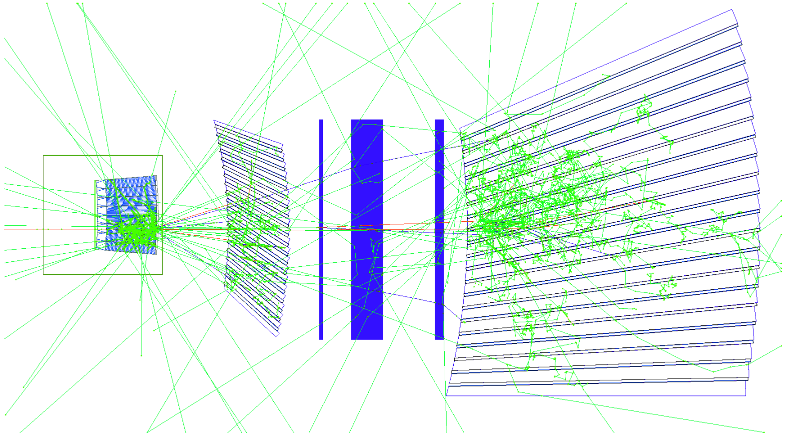


EMCAL towers



HCAL tiles

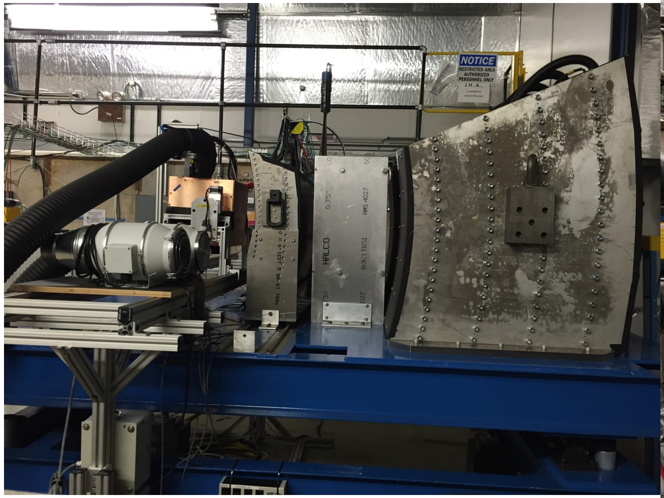


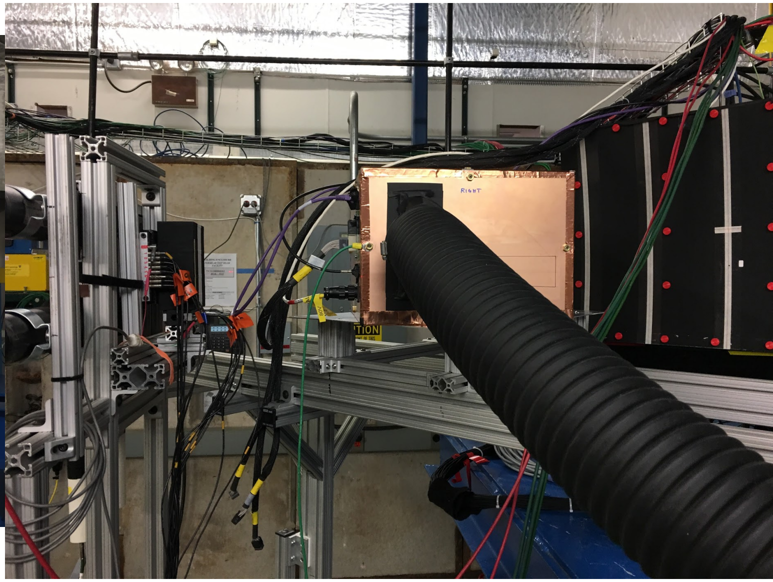


GEANT4 simulation

FTBF T-1044

Calorimeter beam tests





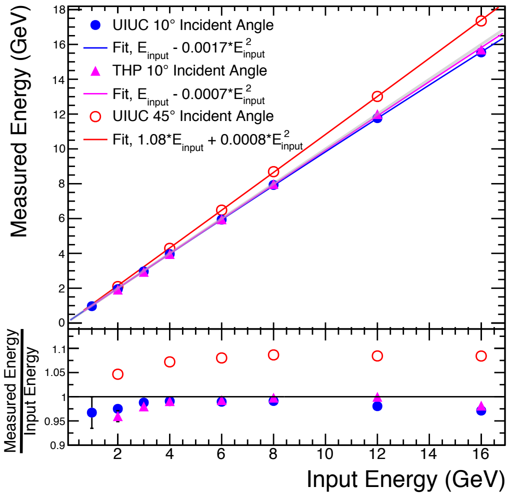
February 2014
Proof of principle

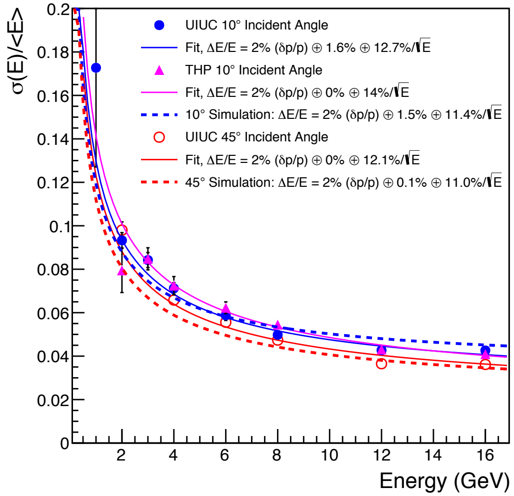
February 2016
$\eta \sim 0$
sPHENIX geometry

https://arxiv.org/abs/1704.01461

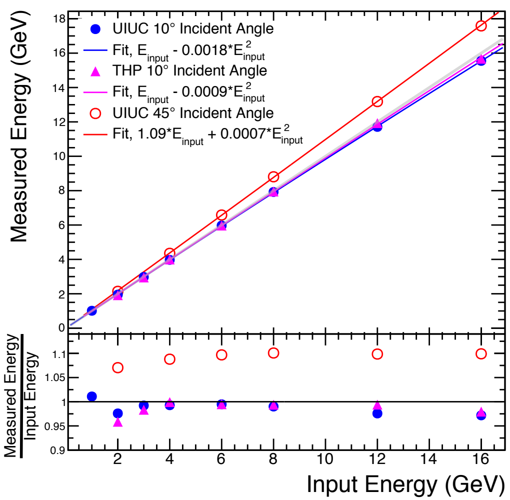
February 2017
$\eta \sim 0.9$

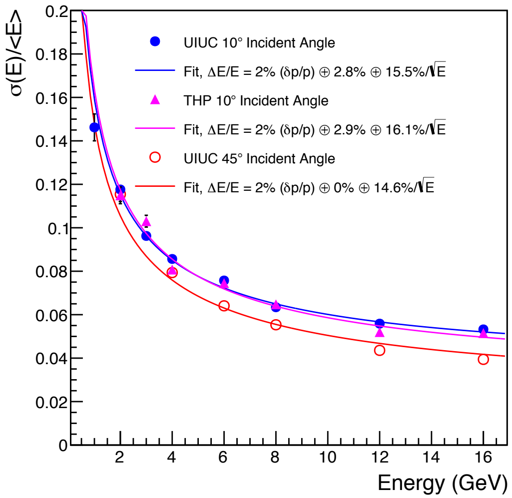
EMCAL η~0 beam test





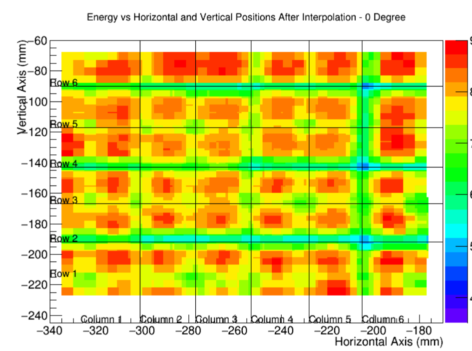
Tower center





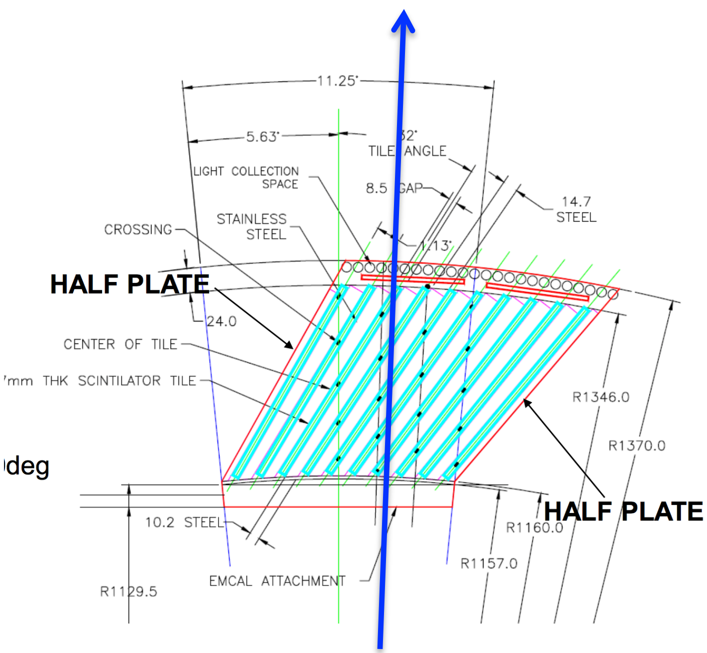
Entire tower

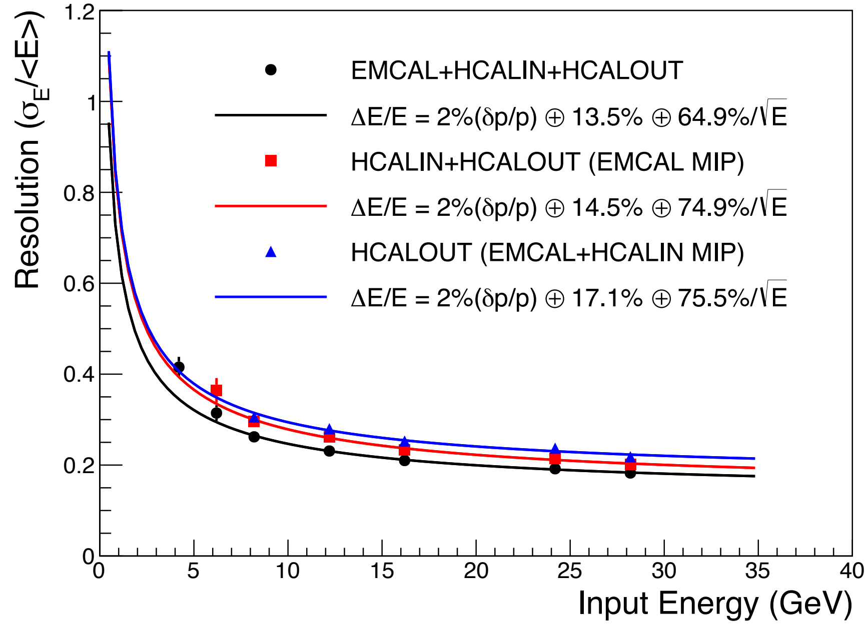
The beam tests taught us to be more meticulous about uniformity and boundaries and ways to correct for it… systematic mapping in η~0.9 beam test



HCAL η~0 beam test

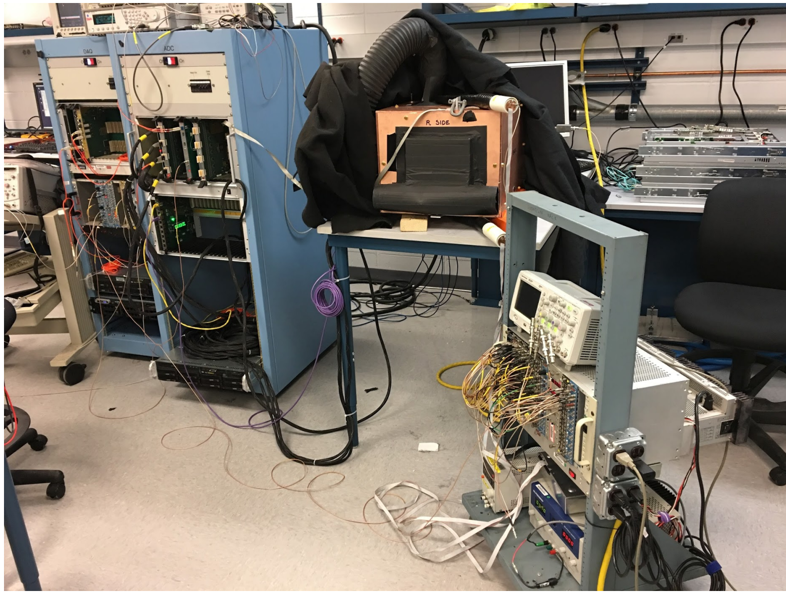
- Learned calibration techniques, energy response uniformity in tiles





Next steps in calorimetry

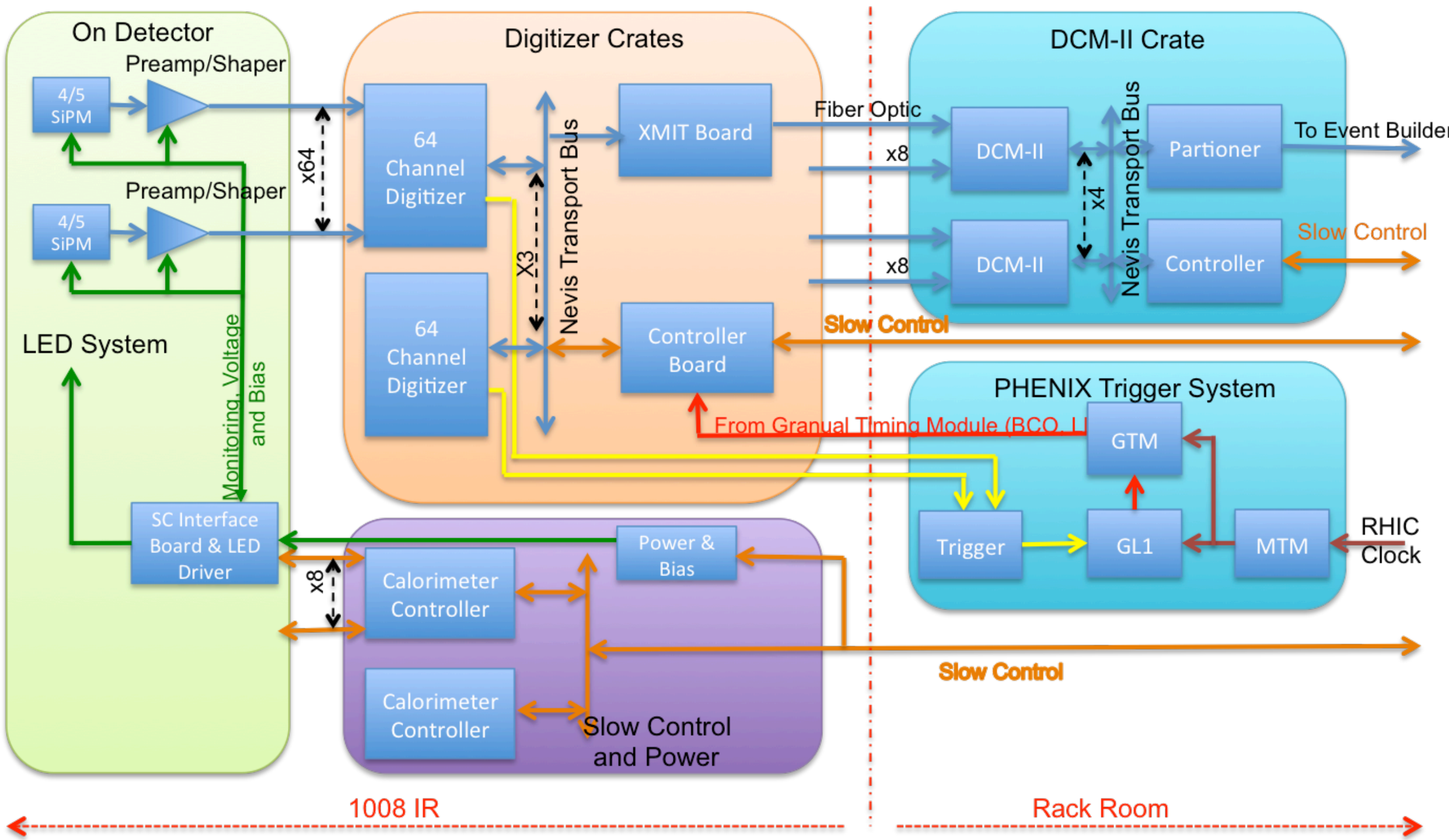
- “Module 0” prototypes of HCAL this year, half-sector of EMCAL next year
- Back to test beam February 2018 with new “production” η~0.9 calorimeters, new “production” digitizers
- By this time next year, we aim to have built and operated every piece of the EMCAL and HCAL



Calorimeter electronics

- Preamplifiers on the detector which drive differential analog signals out to racks about 10 m away
- Waveform digitizers (60 MHz) packaged in VME which transmit data to DCM II's in counting house
- Low voltage, bias voltage, control, temperature compensation
- Purchase and characterization of SiPM's for calorimeter

Calorimeter electronics



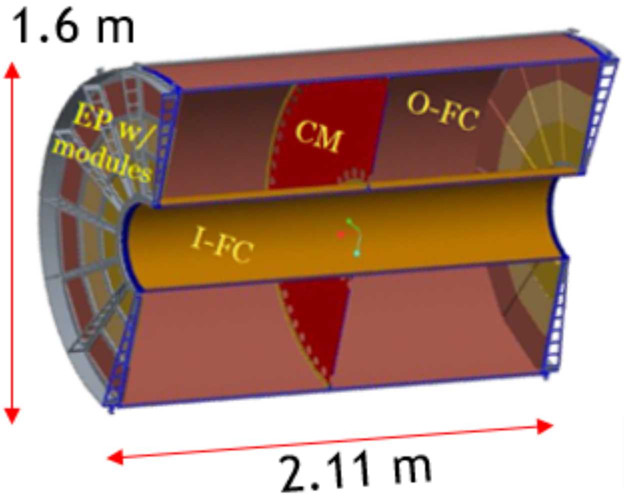
Solenoid magnet

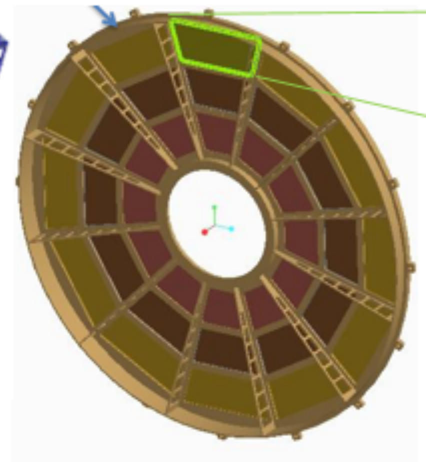
- High resolution tracking translates to high field
  - 1.5 T
  - 2.8 m bore
  - 3.8 m long
- BaBar solenoid arrived at BNL in February 2015
  - Low field test March 2016
  - Preparing now for high field test September 2017
- Cryo, power supply, and quench protection for 1008 under development
- By this time next year, we aim to have tested the magnet at full field

TPC key features

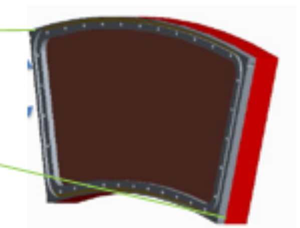
- Compact—outer radius 80 cm
- 3 (radial) x 12 (azimuthal) GEM chambers per end
- FEE board being developed around SAMPA ASIC to be used by ALICE and STAR iTPC (no new ASIC development)
- Fast gas low diffusion to achieve position resolution < 200 μ
- Field distortions minimized by
  - Minimize Ion Back Flow by judicious choice of electric field between GEM foils, pioneered by ALICE
  - Gas choice (low mass, fast drift)
  - High electric field
  - Inner field cage 30→20 cm
- Continuous readout

TPC detector overview





72 modules
2(z), 12(ϕ), 3(r)



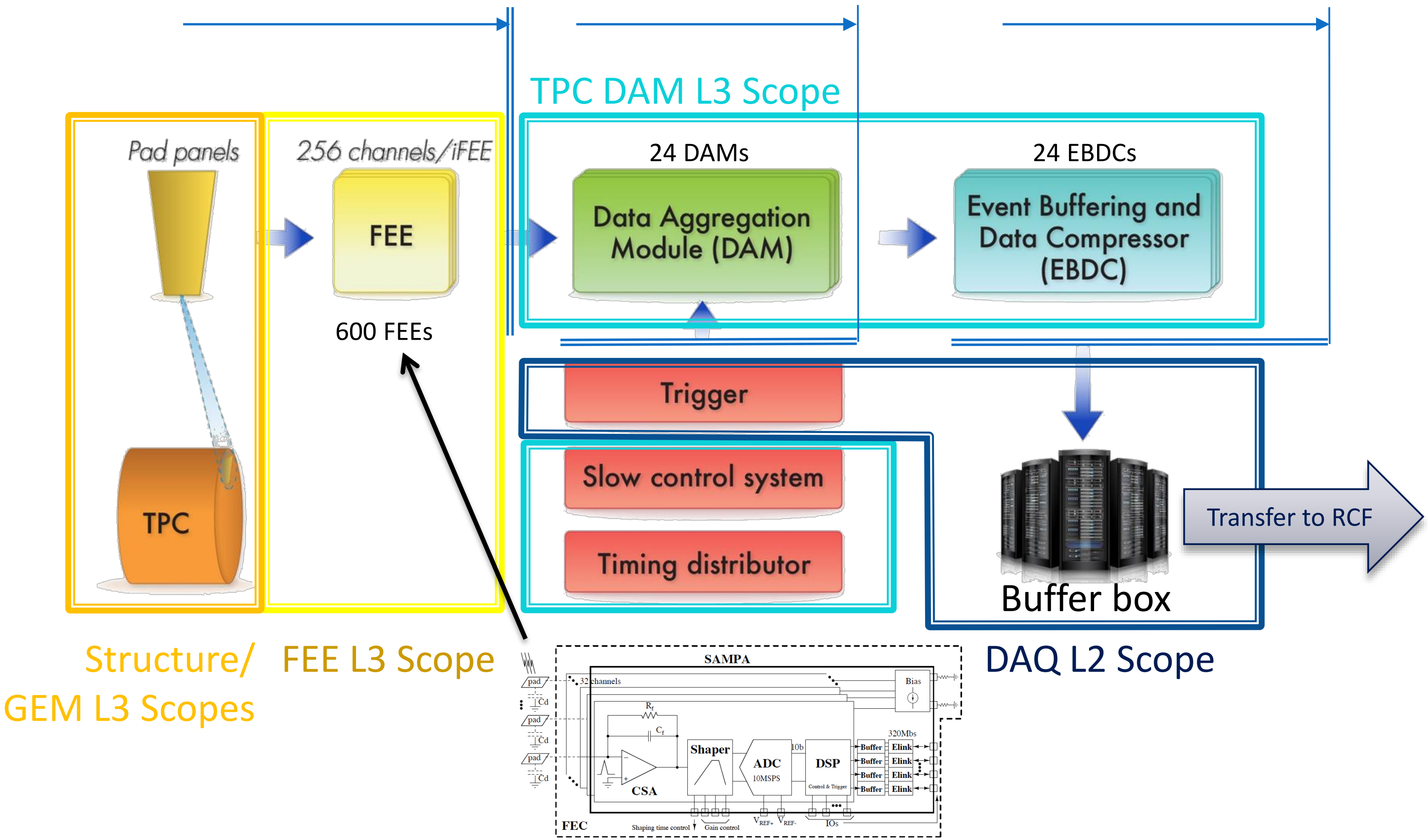
Quad-GEM Gain Stage
Operated @ low IBF

TPC electronics overview

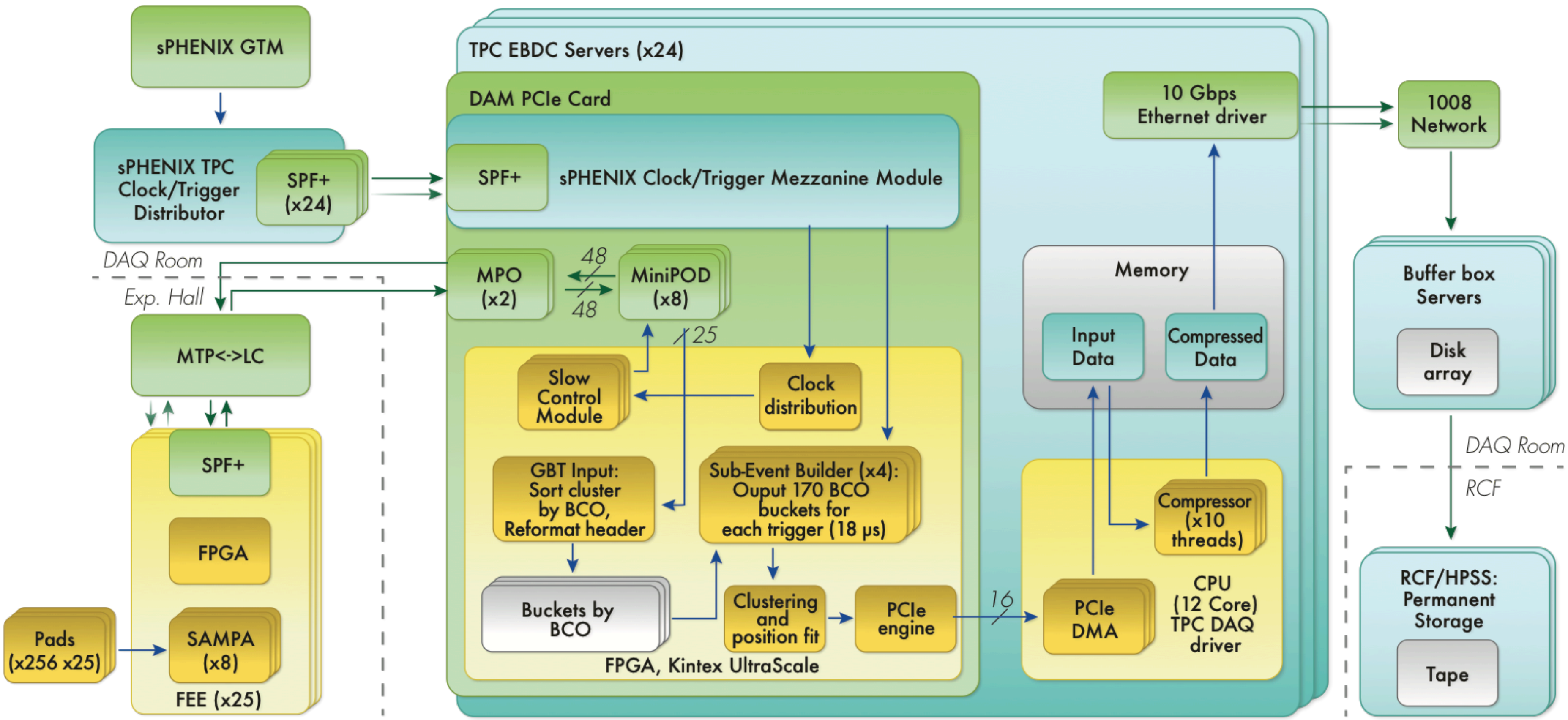
FEE → DAM data stream:
600 fibers total, max 10-Gbps fiber link
Max continuous rate: 2 Gbps / fiber
Average continuous rate: 1.6 Gbps / fiber

Clock/Trigger input:
Fiber, protocol TBD
Clock = 9.4 MHz
Trigger Rate = 15 kHz

Output data stream to buffer box:
24 x 10 Gbps Ethernet
Buffer data in counting house,
then send to RCF for tape storage



DAM and EBDC as envisioned using ATLAS FELIX board



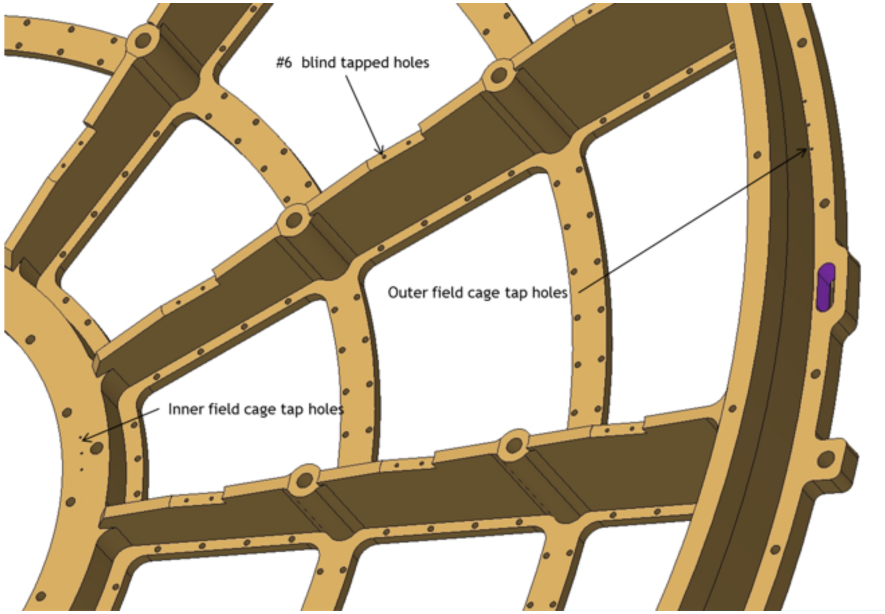
24 sectors, 144k Pads and 600 FEEs in total
1 sector, 25 FEEs per DAM for readout

Table 3.4: TPC DAM and EBDC rate estimation

	Unit count	Rate per unit	Total rate	Assumptions and comments
Data on FEE Fibers	600 fibers	1.6 Gbps	940 Gbps	100kHz Au+Au collision assumed. Rate is radial position dependent. The max data rate is 2 Gbps for the inner-radius FEEs.
Data in BCO-buckets	24 DAMs	40 Gbps	970 Gbps	Unpack SAMPA data and add two 10-bit header per wavelet
After triggering	24 DAMs	11 Gbps	280 Gbps	Event builder collect 170-BCO buckets of hits after each trigger. This reduce data to 29%
After clustering	24 DAMs	5.7 Gbps	140 Gbps	Cluster finding and fitting on DAM FPGA. Expecting a reduction of total data volume to 50% based on STAR and ALICE experience.
After compression	24 EBDCs	3.4 Gbps	80 Gbps	Lossless compression on EBDC CPUs. Assuming the PHENIX experience of a reduction of total data volume to 60%
Buffer box data logging	Buffer box system	80 Gbps	80 Gbps	Logging TPC data to disk in buffer box system in sPHENIX counting house.

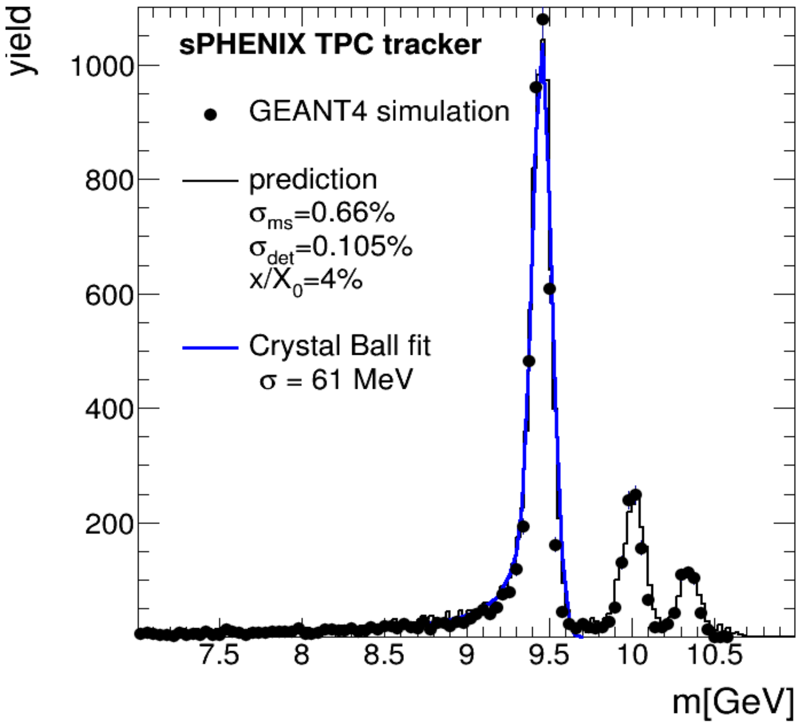
Field cage and mechanics

- Mechanical design and analysis very advanced
- Full size prototype under construction at SBU
- Up to 80 kV high voltage material tests
- Attempt to optimize pad design



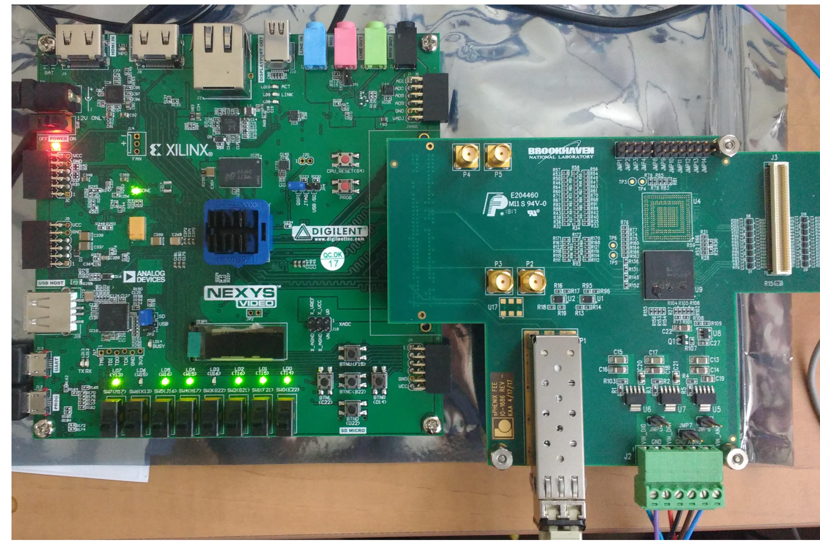
Tracking simulation

- Comprehensive tracking simulation and reconstruction is under way and aim to model realistic cluster size and two hit resolution
- Material budget and incorporation of hits from INTT and MVTX to be included
- Pattern recognition and fitting under intense scrutiny



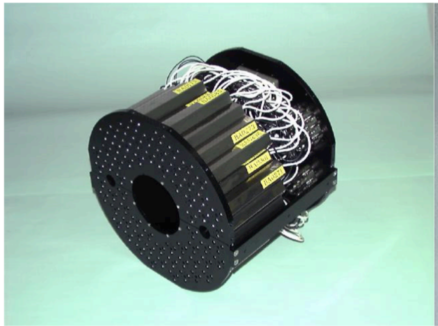
Next steps in TPC

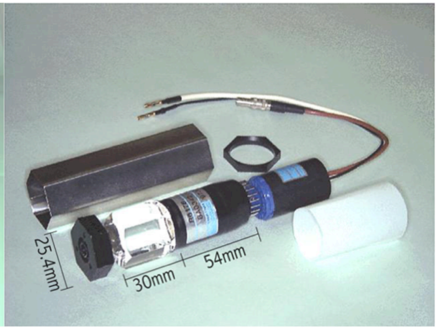
- Complete and test prototype field cage
- Prototype FEE card
- Set up tests with FELIX board
- Inner Region Integration Task Force
- Simulations
- Consider how we can do a truly comprehensive system test

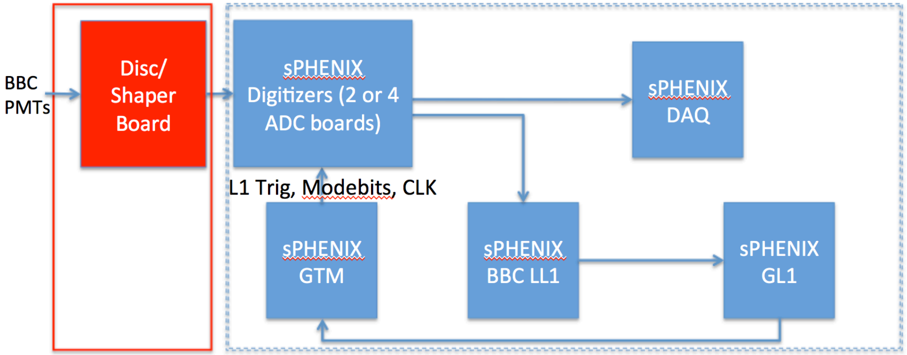


Minimum Bias Detector

- This detector was the PHENIX BB counter and we expect to use it in sPHENIX
- Existing electronics could be resurrected, but development of a relatively simple shaper board would allow us to use the new calorimeter electronics
- PHENIX BB operated in a magnetic field, some testing and judicious choice of location is needed
- Trigger based on calorimeter trigger will be needed





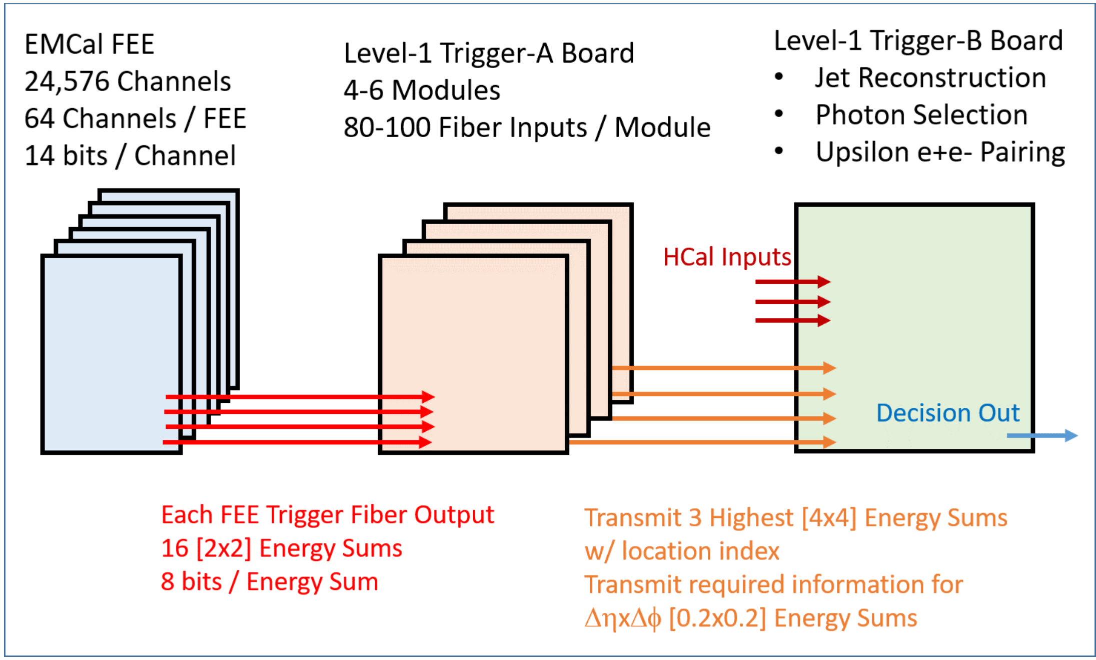


DAQ

- Calorimeter readout uses a modest DCM II's developed for PHENIX, as does INTT
- Tests with DCM II indicate 15 kHz/90% live should not be a problem
- Modest redesign of timing system and trigger manager ("GL1" in PHENIX parlance)
- TPC readout has been described, and provides a significant challenge in data volume and rates
- Data logging rate feasible today, likely to be even more feasible in five years

Trigger

- Calorimeter electronics is designed with hooks on the backplane for trigger primitives
- Trigger studies/ simulation under way



Summary

- We are building sPHENIX with a philosophy of prototype/test/simulate/review to limit surprises at first collisions
- Calorimeter and calorimeter electronics very far along the development arc and have achieved required performance; could be ready for production next year, with experience of constructing and handling full size prototypes
- The magnet will be tested at full field in the next few months
- The TPC and the TPC electronics are deep into development, and rely on technology being developed for ALICE and STAR
- The MBD detector exists and needs a modest amount of testing and development
- DAQ and Trigger build on PHENIX experience, but need the first round of hardware to establish that the reference design is practical

BACKUP MATERIAL

INTT